TECHNICAL REPORT A-77-1

EVALUATION OF HERBICIDE APPLICATION PLATFORMS FO[R] USE IN AQUATIC PLANT CONT[ROL]

Report 1

EVALUATION OF THE MARSH SCREW AMPHIBIAN (MSA)

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February 1977

Report 1 of a Series

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report A-77-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATION OF HERBICIDE APPLICATION PLATFORMS FOR USE IN AQUATIC PLANT CONTROL, Report 1, Evaluation of the Marsh Screw Amphibian (MSA)		5. TYPE OF REPORT & PERIOD COVERED Report 1 of a series
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edgar S. Rush William E. Willoughby		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Mobility and Environmental Systems Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE February 1977
		13. NUMBER OF PAGES 40
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) WES-TR-A-77-1		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

(9) (6) (10) (11) (14) (12) 44p.

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic plant control
Herbicides
Marsh Screw Amphibian
Screw propelled vehicles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this report was to document the results of field demonstrations of the Marsh Screw Amphibian (MSA) and to discuss the capabilities of the MSA and other screw-propelled machines and the potential of their unique locomotion principle for transport platforms for aquatic plant herbicide application systems. Herbicides are normally applied to aquatic plants in open water by the use of aircraft, airboats, motorboats, and in

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038 100

20. ABSTRACT (Continued).

some instances, land-based vehicles. Control operations in open water could be significantly reduced if access could be gained to those areas in which aquatic plants regenerate and develop, mainly the tree- and stump-dotted backswamps, access canals, and shallow mud flats surrounding large inland water bodies and along slow-moving rivers. Treatment of aquatic plant breeding grounds from currently available carriers is often impractical; therefore, this study of the MSA was performed. The field demonstrations were carried out in southern Louisiana in areas where the current assortment of boats used for control operations has difficulty maneuvering. The general consensus of observers of the demonstration was that further investigations of the use of screw-propelled machines is warranted; however, additional evaluation of the MSA itself was not justified because of certain design deficiencies.

Based on this study, it was recommended that the MSA be modified to correct the current deficiencies and then be reevaluated. Appendix A discusses four other screw-propelled machines, and Appendix B describes highway transporters for screw-propelled vehicles.

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PREFACE

The study presented herein was sponsored by the Aquatic Plant Control Research Program of the Directorate of Civil Works, Office, Chief of Engineers, who provided funds under Department of the Army Appropriation No. 96X3122, "Construction General."

All phases of this study were conducted from April through September 1975 by the Mobility and Environmental Systems Laboratory (MESL), U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Messrs. W. G. Shockley, Chief, MESL, A. A. Rula, Chief, Mobility Systems Division (MSD), and B. O. Benn, Chief, Environmental Systems Division (ESD), and under the direct supervision of Mr. J. L. Decell, Chief, Aquatic Plant Research Branch (APRB), ESD.

Mr. S. O. Shirley, APRB, conducted the field demonstrations with the cooperation and assistance of Mr. W. E. Thompson, Chief, Aquatic Plant Control Section, U. S. Army Engineer District, New Orleans. Messrs. E. S. Rush and W. E. Willoughby, MSD, prepared the report.

Directors of the WES during the collection of the data and preparation of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, METRIC (SI) TO U. S. CUSTOMARY AND U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
Metric (SI) to U. S. Customary		
metres	3.280839	feet
kilometres	0.6213711	miles (U. S. statute)
kilograms	0.001102311	tons (short)
kilograms per square metre	0.2048	pounds (mass) per square foot
kilometres per hour	0.6213711	miles (U. S. statute) per hour
U. S. Customary to Metric (SI)		
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
cubic inches	16.38706	cubic centimetres
cubic feet	0.02831685	cubic metres
gallons (U. S. liquid)	0.003785412	cubic metres
gallons (U. S. liquid) per hour	0.003785412	cubic metres per hour
tons (short)	907.1847	kilograms
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
miles (U. S. statute) per hour	1.609344	kilometres per hour
horsepower (550 foot-pounds per second)	745.6999	watts
degrees (angular)	0.01745329	radians

EVALUATION OF HERBICIDE APPLICATION PLATFORMS FOR USE IN AQUATIC PLANT CONTROL

EVALUATION OF THE MARSH SCREW AMPHIBIAN (MSA)

PART I: INTRODUCTION

Background

1. Herbicides are normally applied to aquatic plants in open waters by the use of aircraft, airboats, motorboats, and in some instances, land-based vehicles. Control operations in open water could be significantly reduced if access could be gained to those areas in which the aquatic plants regenerate and develop, mainly the tree- and stump-dotted backswamps, access canals, and shallow mud flats surrounding large inland water bodies and along slow-moving rivers. Treatment of the aquatic plant breeding grounds from currently available carriers is often impractical. Herbicide distribution from aircraft lacks the control needed to prevent damage to surrounding vegetation, airboats lack maneuverability among tree- and snag-covered swamps, and motorboats have difficulty in shallow water-covered mud flats and dense growths of vegetation. Thus, a carrier is needed to transport herbicide application systems into areas that are primarily inaccessible with currently available transport systems. A carrier that uses the unique Archimedean screw locomotion principle appears to have potential and is the subject of this report.

2. The first practical application of this unique principle is attributed to COL John Stevens[1] (later founder of Stevens Institute of Technology), who in 1804 built and operated a screw-driven steamboat on New York's North River. In the late 1920's, a Fordson tractor was modified and equipped with screw rotors for duty over snow and ice. A screw-driven amphibious tractor was proposed in England in 1948 by LTC H. O. Nelson, and a German firm demonstrated an independently developed prototype screw amphibian at the 1957 Hanover exhibition.

In the early 1950's, a modified (M29C) weasel, with screw propulsions instead of tracks, was experimented with in Greenland by the U. S. Army. Since 1960, several vehicle concepts using screw propulsion have been studied[2-6] (see also Appendix A). Notable among these are the Marsh Screw Amphibian (MSA), the Riverine Utility Craft (RUC), the AMFIROL, the Twilighter, and the Amphibious Mud and Water Vehicle. There may be others, but time and funds did not permit a detailed search of literature. Prototypes of the MSA and the RUC have been built and tested previously for application in a military logistics role by the U. S. Armed Forces. The AMFIROL is built and marketed by a firm in Holland for various civil purposes. The Twilighter and the Amphibious Mud and Water Vehicle have not been constructed but are discussed briefly in Appendix A because of the unique characteristics incorporated in their design.

3. The U. S. Army Engineer Waterways Experiment Station (WES) has studied the performance of the MSA and the RUC and suggested that these vehicles could operate well in the areas that were inaccessible by the conventional vehicles discussed in paragraph 1. In March 1974, the U. S. Army Engineer District, New Orleans, requested that the WES demonstrate the Archimedean screw locomotion principle at selected sites typical of aquatic plant-infested areas that were extremely difficult or impossible to negotiate with conventional vehicles. The MSA was selected as the demonstration vehicle, and after its extensive mechanical overhaul was completed in April 1975, the demonstration was carried out during the first two weeks in June 1975.

Purpose and Scope

4. The purpose of this report is to document the results of the MSA demonstration conducted for the New Orleans District and to discuss the capabilities of the prototype MSA and other screw-propelled machines and the potential of their unique locomotion principle for transport platforms for aquatic plant herbicide application systems.

5. Vehicle and performance characteristics of the MSA are

presented, along with a comparison of its performance with the known performance of various water and ground vehicles that have potential as transporters for equipment used in aquatic plant control operations. Part II describes the demonstration areas, the MSA, and the tests conducted during the demonstration. Part III presents the test results and a comparison of the performance of the MSA and other land and water vehicles. Part IV summarizes the conclusions and recommendations. Appendix A presents a brief description of other screw propelled vehicles: the RUC, the AMFIROL, the Twilighter, and the Amphibious Mud and Water Vehicle. Appendix B describes highway transporters for screw-propelled vehicles.

PART II: DEMONSTRATION PROGRAM

Demonstration Areas

6. Effective application of herbicides in the New Orleans District requires the use of transporters capable of operating over the wide variety of terrain conditions found in the aquatic environment. A review of the problem areas revealed that an ideal transporter would have to operate to some degree over the following terrain features: (a) firm soil; (b) sloping canal banks; (c) mud flats; (d) wooded swamps; (e) shallow, open water; (f) deep, open water; (g) shallow water with surface aquatic plants; (h) deep water with surface and subsurface aquatic plants; (i) long, narrow, open canals; (j) long, wide, open canals; (k) long, narrow canals with dense vegetation; and (l) long, wide canals with dense vegetation.

7. Prior to conducting the demonstration, the New Orleans District and the WES personnel made a field reconnaissance to select convenient locations that had as many of the conditions listed above as possible. Three areas in southern Louisiana were selected for the MSA demonstration: one near New Orleans, Louisiana; one south of Houma, Louisiana; and the third area at Lake Boeuf northeast of Houma (Figure 1).

New Orleans

8. This area was a drainage ditch adjacent to U. S. Highway 61, 5.2 km* west of the New Orleans International Airport. Two test lanes 30 m long were established parallel to each other in the ditch. As shown in Figure 2, the area was 100 percent vegetated, mainly with floating waterhyacinths (Eichhorniae crassipes), although various species of grasses (bristle, barnyard, vasey, etc.) and other vegetation were scattered throughout the area. Water in the ditch was 0.65 m deep.

Houma

9. South of Houma, Louisiana, and on both sides of Louisiana

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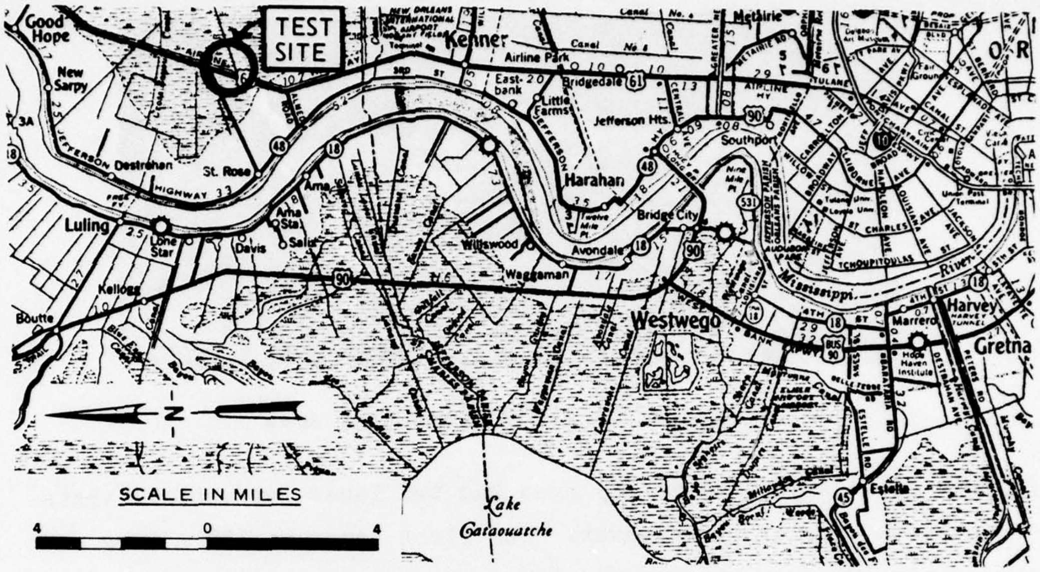
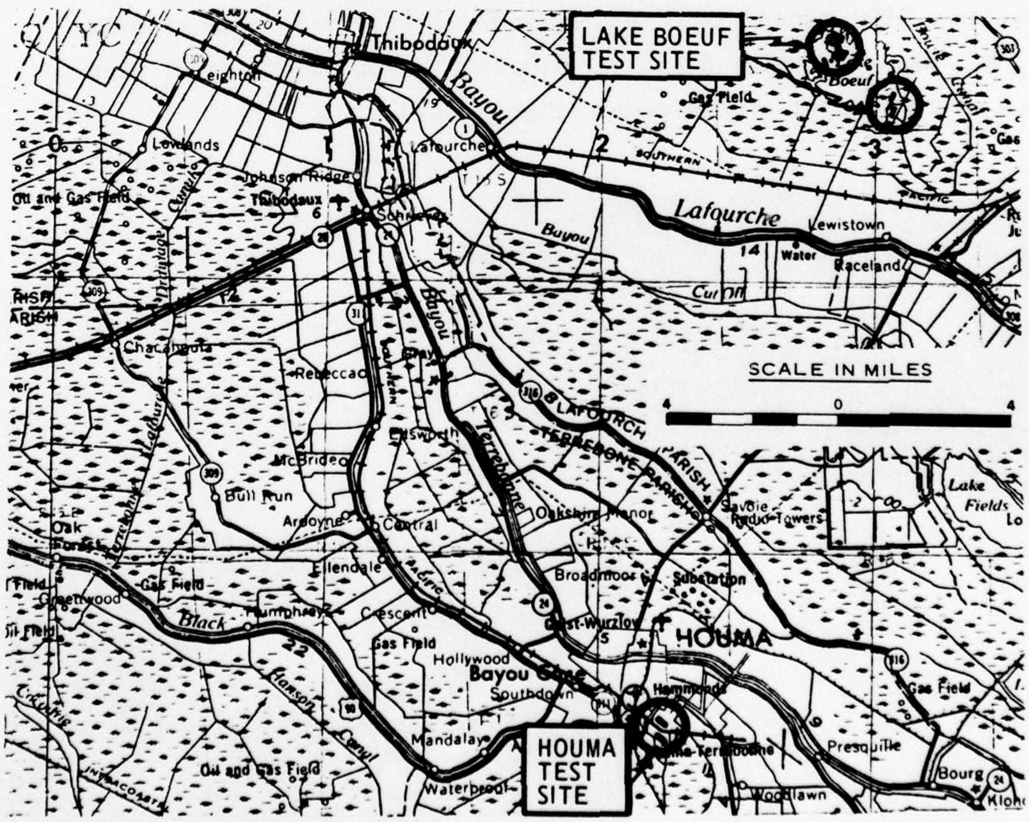
* A table of factors for converting metric (SI) units of measurement to U. S. customary units and U. S. customary units to metric (SI) units is given on page 4.



a. New Orleans test site



b. Houma and Lake Boeuf test sites

Figure 1. MSA demonstration test sites

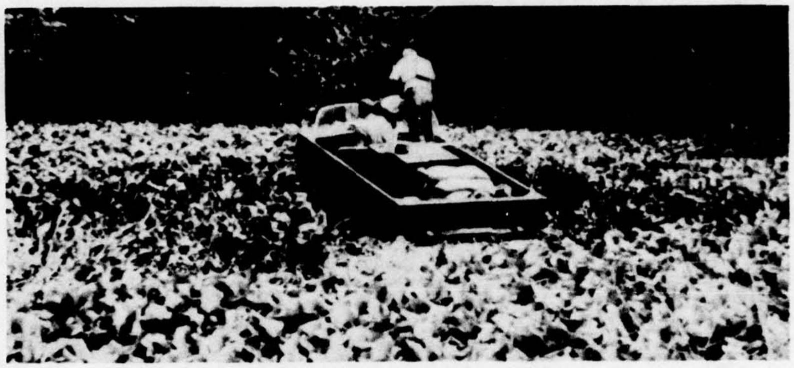
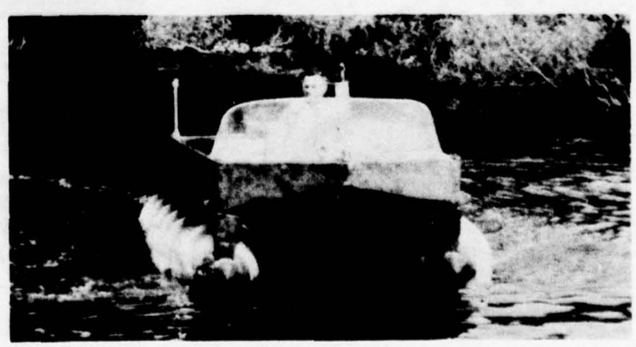


Figure 2. New Orleans test area

Highway 3040, this flat marshy area had two lanes for vehicle tests, one on each side of the highway. The first lane was 150 m long and was nearly 100 percent covered with vegetation consisting of water-hyacinths and alligatorweed (Figure 3a). Water was 1.2 m deep in this test lane. The second lane was a nonvegetated, open-canal crossing 21.5 m long, with water depth varying from 0.9 m at the canal edge to 2.2 m at the center of the canal (Figure 3b).

a. Typical vegetation



b. Open-water tests

Figure 3. Houma test area

Lake Boeuf

10. Two test lanes were selected in open water in Lake Boeuf, five in a vegetated area around Lake Boeuf Island (represented by Figure 4a), and two in a canalled area southeast of Lake Boeuf Island adjacent to the shores of Lake Boeuf (Figure 4b). The lanes were of the following lengths: 150 and 150 m (open water); 62, 51, 43, 73, and 93 m (vegetated area); and 392 and 210 m (canalled area). All vegetated lanes were essentially the same, relative to test conditions, with each beginning in an area of open water, then traversing a vegetated, marshy area, and ending in open water. The primary vegetation in each lane was water-hyacinth, although some marsh grasses and other submerged (Brazilian Elodea, fanwort), floating (duckweed, watermeal), and emersed (fragrant waterlily) vegetation were scattered throughout the vegetated areas (Figure 4c). Water was generally about 1.3 to 1.5 m deep in all test lanes, including the open-water test lanes.

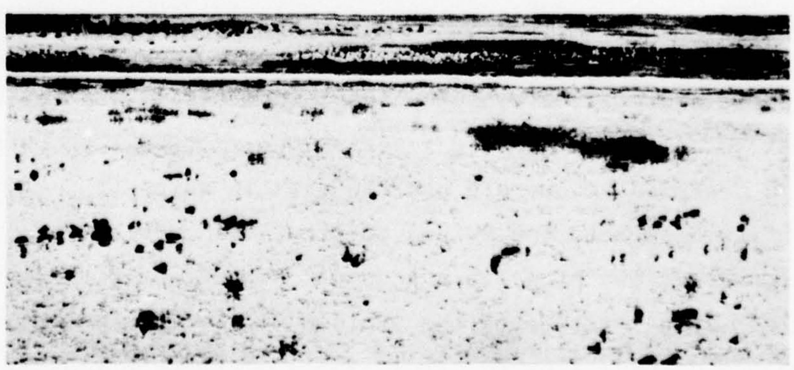
Marsh Screw Amphibian (MSA)

11. As stated in paragraph 3, the MSA was selected to demonstrate the potential of a transport vehicle using the Archimedean screw propulsion principle. Two prototype vehicles were designed and built by Chrysler Corporation Defense Engineering in the 1960's for the Department of the Navy. Both are at the WES, and one was overhauled specifically for this demonstration.

12. The Marsh Screw's unusual concept of locomotion, consisting of two threaded cylinders as rotating pontoons, places it outside the normal tracked and wheeled vehicle classifications. "The vehicle's name is the best possible, three-word description. Marsh is the area in which it is designed to operate and the area in which it performs best. The word Screw describes the method of propulsion, which is based on the Archimedean screw, two of which are used. Amphibian is the general vehicle classification because the vehicle will run on water, marsh, and on many land conditions."[2] Photographs of the vehicle are presented in Figure 5.

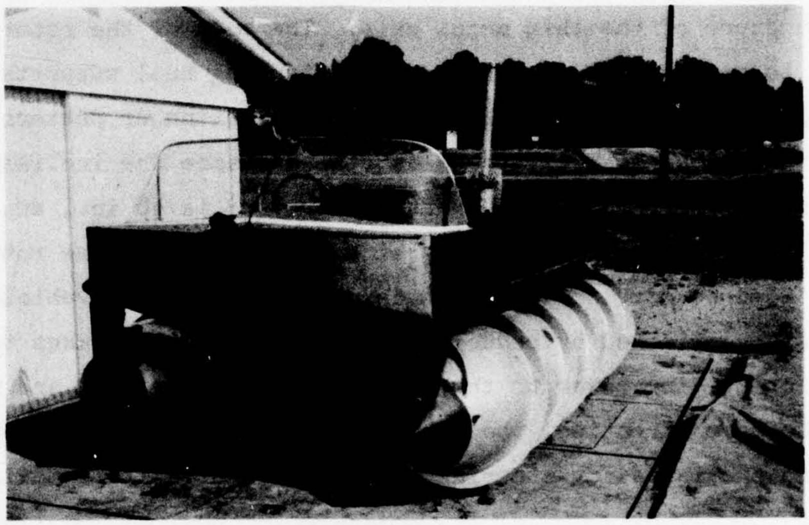
a. Representative vegetation

b. Canal vegetation

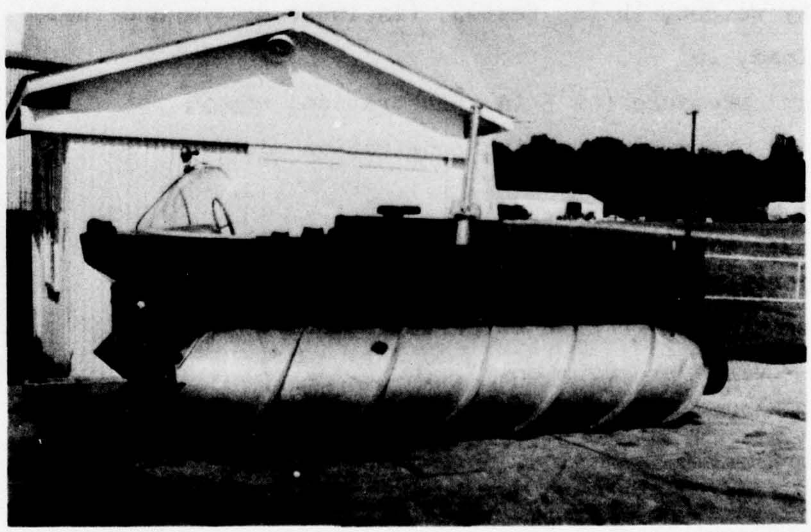


c. Typical vegetation

Figure 4. Lake Boeuf area



a. Front view



b. Side view

Figure 5. Different views of the MSA

Vehicle characteristics

13. The vehicle travels on two tapered-end cylinders or rotors. Each rotor is filled with polyurethane foam to prevent entry of water in case of puncture of the thin metal skin. The ends of the rotors are truncated to provide a flat section for attaching hull supports. Two helical blades are welded to each rotor in a continuous pattern from front to rear. The lead of the helix (the distance the inclined helix travels in one complete circle around the rotor) is 48 in., and the helix angle is approximately 32 deg with the vertical. The rotors are counterrotated to give forward or backward thrust to the vehicle. Turning is accomplished by reducing power and applying brakes to one rotor while applying power to the other. When both rotors are made to turn in the same direction, the vehicle will move laterally; however, there is no provision for steering the vehicle while it is moving laterally.

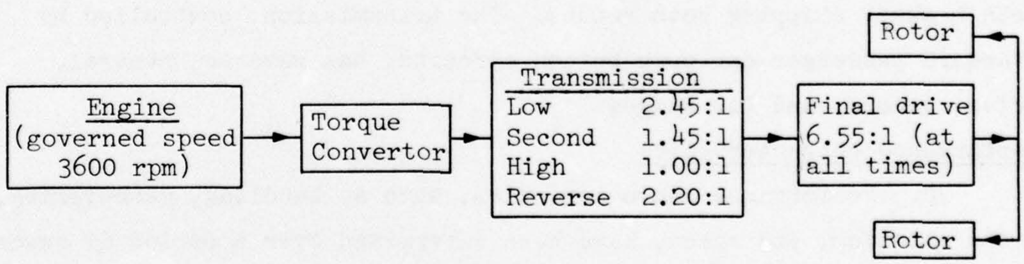
14. Pertinent data on the model of the MSA tested are tabulated below:

Empty weight, lb (as tested) (includes driver and fuel)	2860.00
Payload, lb	1094.00
Ground pressure (at 3-in. penetration) empty, psi	0.52
Ground pressure (at 3-in. penetration) loaded, psi	0.72
Length, overall, ft	13.66
Width, overall, ft	8.16
Height, overall, ft	4.75
Rotor spacing (center to center), in.	66.00
Rotor diameter (drum only), in.	26.00
Rotor diameter (over helix), in.	31.00
Rotor length (overall), in.	152.00
Rotor length (in contact with ground, no rut), in.	129.50
Ground clearance, in.	20.00
Engine	
Make	Chrysler
Model	RG Special

Type	Spark ignition, slant 6 cyl, water-cooled
Bore and stroke	3.40 by 4.25 in.
Displacement	225 $in.^3$
Governed speed	3600 rpm
Net horsepower, brake	116 at 3600 rpm
Electrical system	12 v/w alternator
Materials	
Body and rotors	6061 T6 aluminum
Engine block	Aluminum*
Transmission housing	Aluminum
Final drive housing	Aluminum

Power train

15. Power is transmitted from the engine through a torque convertor and the transmission to a final chain drive connected to the rotors. The following is a schematic flowchart:



16. If there is no slip between the rotors and surface media (soil or water), the vehicle moves 4 ft forward with each revolution of the rotors; at 1.5 mph the rotors turn at a rate of 33 rpm, and at 10 mph the rotors turn at a rate of 220 rpm.

17. With its present engine and power train gear ratios, the MSA is grossly underpowered in certain surface terrain situations, such as on deep, sticky clays and on firm soils with no surface water present to

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* Presently equipped with cast-iron block that adds slightly to the overall weight of the vehicle.

lubricate the rotors. The power problem can be corrected; corrective actions will be discussed later.

Handling controls

18. The steering wheel is connected to a series of limit switches and to a specially wound rheostat. When the wheel is turned to the right, the rheostat reduces the torque capacity of the clutch to the right rotor continuously and at 90 deg starts to apply the brake current to the right side. Continued turning to the right eliminates all right-hand clutch torque and increases the right-hand brake torque to stop the right-hand rotor. Additional controls are provided in the form of two switches that control the left and right clutches. This is useful for sideways operation on land.

19. Throttle control is conventional in that a foot throttle is in the normal position on the floorboard and connected through a throttle cable to the carburetor. A hand throttle also is mounted on the right-hand side of the instrument panel. An electric foot brake mounted on the left side of the accelerator pedal on the floor applies both brakes, stopping both rotors. The transmission, controlled by standard passenger-car push-button circuits, has reverse, neutral, drive, second, and low ranges.

Performance characteristics

20. Performance characteristics, such as handling, maneuvering, slope climbing, and speed, have been determined over a period of several years as a result of three major field programs and a series of scale-model tests. A 100-hr test program was conducted by the Chrysler Corporation[2] as part of the requirements of the development contract. The purpose of this test program was to accumulate operational experience and performance data when the MSA was operating in environments that closely approximated those in Southeast Asia. A WES test program[7] was conducted to quantify the MSA performance in soft soil. A military-potential test program[8] was conducted by the U. S. Army General Equipment Test Activity to evaluate the performance capabilities in both firm and soft soils and in vegetated water channels and lakes. The scale-model

tests were made by Stevens Institute[1] to observe certain performance characteristics in sand and mud.

21. The general performance characteristics of the MSA, as determined from the measurements and observations made during the abovementioned test programs, are summarized in the following tabulation.

Item	Condition	Performance
Speed	Open water	15.8 km/hr (driver only)
	Open water	12.2 km/hr (driver and payload)
	Dry soils and sand	3.2 km/hr
	Wet, soft clay	32.2 km/hr
Climbing	Clean slopes	60 percent (for elevation difference, 0.9 m)
Side-slope capability	Vegetated	30 percent
Maneuverability	Open water, 180-deg turn	4 vehicle lengths (high speeds)
		1-1/2 vehicle lengths (low speeds)
Operating range	Not applicable	6 hr at full throttle

Figures 6-8 show the MSA operating in various conditions during the test programs.

Test Procedures, Tests Conducted, and Data Collected

22. Three types of tests were conducted in the selected test lanes: straight-line speed tests, general maneuver tests (usually "Figure-8" tests), and one canal-crossing test. In each speed test, the vehicles accelerated up to an optimum speed for the test conditions and

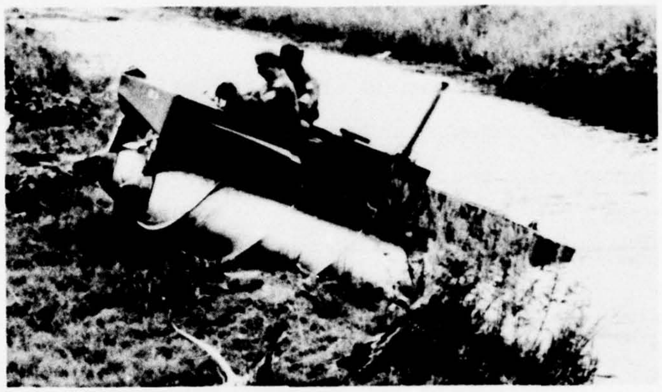

Figure 6. MSA negotiating a canal bank

Figure 7. MSA operating in a tidal mud flat

Figure 8. MSA operating in a vegetated swamp

then entered timing zones in which stopwatch times were measured for determination of average vehicle speed. Problems encountered by the vehicle were noted to ascertain the terrain factors affecting vehicle speed in the test lanes. Vegetation size and density were recorded to determine any effects of vegetation density on vehicle operations. In all tests, the vehicle was operated in the optimum gear configuration for the test conditions, at about 2000 rpm. First and second gears were selected for vegetated areas, and "drive" (gears 1-3) was selected for open-water tests. Results of these tests are shown in Table 1. In each test area, though not necessarily within a specified test lane, a general maneuver test ("Figure-8") was conducted with the vehicle to ascertain steering response and maneuverability in the terrain conditions encountered. No times were collected during these tests. One canal crossing was attempted in which the vehicle negotiated one canal bank, entered the canal and crossed it, and exited on the opposite bank. Times were collected at the water's edge on each bank for canal-crossing speed determinations.

23. In addition to the performance measurements taken in the tests described above, a test observer from the New Orleans District and one from the WES noted, in a qualitative sense, how the vehicle performed during random trials conducted in a variety of terrain conditions. These notes are summarized in the following part of the report.

PART III: ANALYSIS AND OBSERVATIONS

Analysis of Test Results

Speed tests

24. The MSA performed well in most speed tests, experiencing difficulty only in the heavier, thicker areas of vegetation, which usually occurred in confined areas, such as drainage ditches along the roads in the areas. The speeds for the straight-line speed tests in vegetation ranged from 1.6 to 9.8 km/hr, with the speeds usually governed by the density and type of vegetation (Table 1). Figure 9 shows that as the density of the matted vegetation (mostly waterhyacinths), expressed as measured weight of plants per measured surface area, increased, the speed of the vehicle gradually decreased. Further testing would be required, however, to more fully develop this speed relation over a

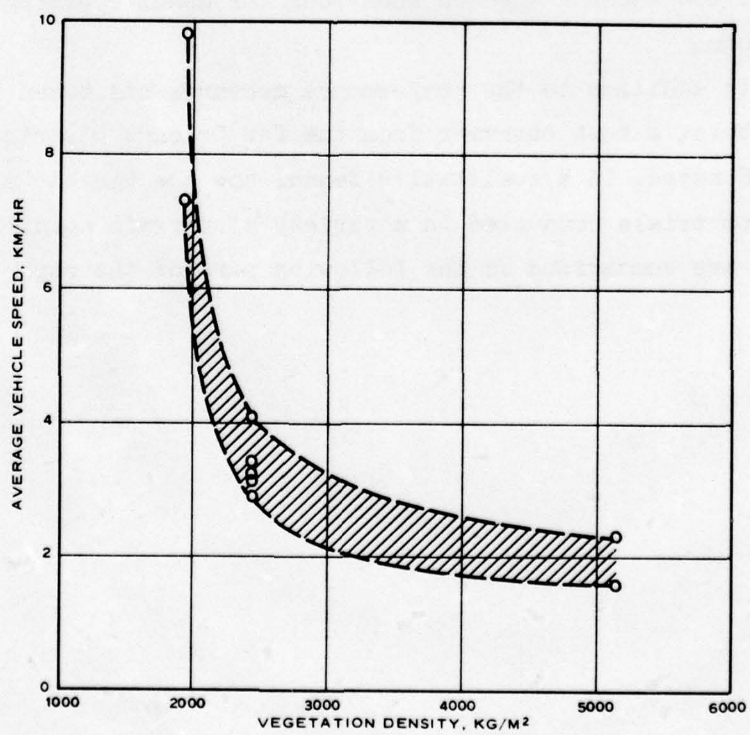

Figure 9. Average vehicle speed versus vegetation density (from Table 1)

range of vegetation types and density. The floating or submerged vegetation had little effect on vehicle speed, because the vehicle rotors were able to push the vegetation down and override it. Usually some surface water was available for rotor lubrication in the floating vegetation, which enabled the vehicle to negotiate some thick floating vegetation with a rather heavy root mat. The only problem in negotiating the test lanes in the straight-line tests occurred in the tests at New Orleans. The vehicle encountered problems negotiating the thick, confined waterhyacinth mats, which broke apart during vehicle passage. As the rotors turned for propulsion, the threads (helix) actually pulled the plants up under the vehicle and broke them apart, preventing the vehicle from climbing up onto and riding on the mat, as occurred in the other vegetated tests. The counterrotation of the helix in toward the bottom of the vehicle was the major contributing factor in whether or not the plants were pushed aside. In all other vegetated tests, the vehicle was able to climb up onto the mat and traverse the test lanes. Variations in vehicle speed were obviously caused by changes in vegetation type and density, which are reflected in the data presented in Table 1 and Figure 9.

Maneuver tests

25. In the maneuver tests, the vehicle was able to negotiate all turns and "Figure-8's" with ease. Some increased difficulty in maneuvering occurred in the open-water tests, but this increase in effort was attributed to the lack of firm material in which the helix of the rotor could gain thrust. In the vegetated areas, the rotors depressed the standing vegetation, and the helix gained thrust from the root mat. Ease of maneuver in these areas was determined by reduction of frictional forces between the vegetation and the rotors by surface water or vegetation fluids.

Canal-crossing test

26. Only one canal crossing was attempted. A 21.5-m-wide canal at Houma was traversed with ease by the MSA at an average speed of 6.2 km/hr. The vehicle had no difficulty in entering or exiting the canal. The relatively slow speed was attributed to the short width of

the canal and the slow entrance and exit speeds, which did not permit the vehicle to reach full throttle at any time during the test.

Observations

27. In addition to the above, several qualitative assessments of the vehicle's performance were noted during this test program. Those assessments deemed pertinent to performance in the aquatic plant problem environments are:

a. There was a noted increase above the water speed when the vehicle operated over lubricated, rooted vegetation.

b. Steering was difficult in free-water conditions.

c. The MSA easily negotiated densely vegetated portions of a canal infested with alligatorweed.

d. The MSA easily negotiated an area covered with an entangled dense floating grass mat 6 to 12 in. thick.

e. The MSA easily negotiated rooted/floating vegetation containing pickerelweed, waterprimrose, duckweed, cattails, and lily pads.

Comparisons of Performances of the MSA and Other Water and Land Vehicles

28. As stated in paragraph 6, effective application of herbicides in the New Orleans District requires the use of transporters capable of operating over the wide variety of terrain conditions found in the aquatic ecosystem. Consequently, any given type of carrier is not adequate for optimum operation in all terrain conditions. The terrain features-vehicles matrix shown on the following page illustrates this fact.

29. The matrix on the following page identifies the terrain feature over or within which a particular machine might operate; however, it does not indicate the degree of performance with respect to the other vehicles. For example, the matrix shows that the screw-propelled vehicles are capable of operating in all terrain features listed, but their speed performance in open water is not nearly as fast as that of

Terrain Features*	Screw-Propelled Vehicles	Tracked Marsh Buggies	Air-boats	Motor-boats	Conven-tional Land Vehicles	Propeller- and Wheel-Driven Amphib-ious Vehicles
Firm soil	X**	X			X	X
Sloping canal banks	X	X			X	X
Mud flats	X	X				
Wooded swamps	X		X			
Shallow, open water	X	X	X			X
Deep, open water	X	X	X	X		X
Shallow water with surface aquatic plants	X	X	X			
Deep water with surface and subsurface aquatic plants	X	X	X			
Long, narrow, open canals	X		X	X		X
Long, wide, open canals	X	X	X	X		X
Long, narrow canals with dense vegetation	X		X			
Long, wide canals with dense vegetation	X	X	X			

* Those features that could affect the performance of the vehicle types listed at top of matrix.

** Denotes that the respective vehicles can operate with some degree of success in the respective terrain condition.

the airboats or the motorboats. However, speed is not the most critical performance criterion during the application of herbicides, since herbicides are most effective when applied uniformly at slow speeds. However, speed is important in traveling from one work area to the next.

30. The next most successful overall performance in these environments is the commercial amphibious tracked marsh buggies; however, they are currently rather large and slow. Airboats are good performers in water-covered areas and vegetation-covered waters at moderate speeds. Motorboats are good performers in open water and waters sparsely covered with vegetation, but they are poor performers in waters with subsurface vegetation that entwines in the propellers.

31. Figure 10 shows a comparison of speed performance ranges of

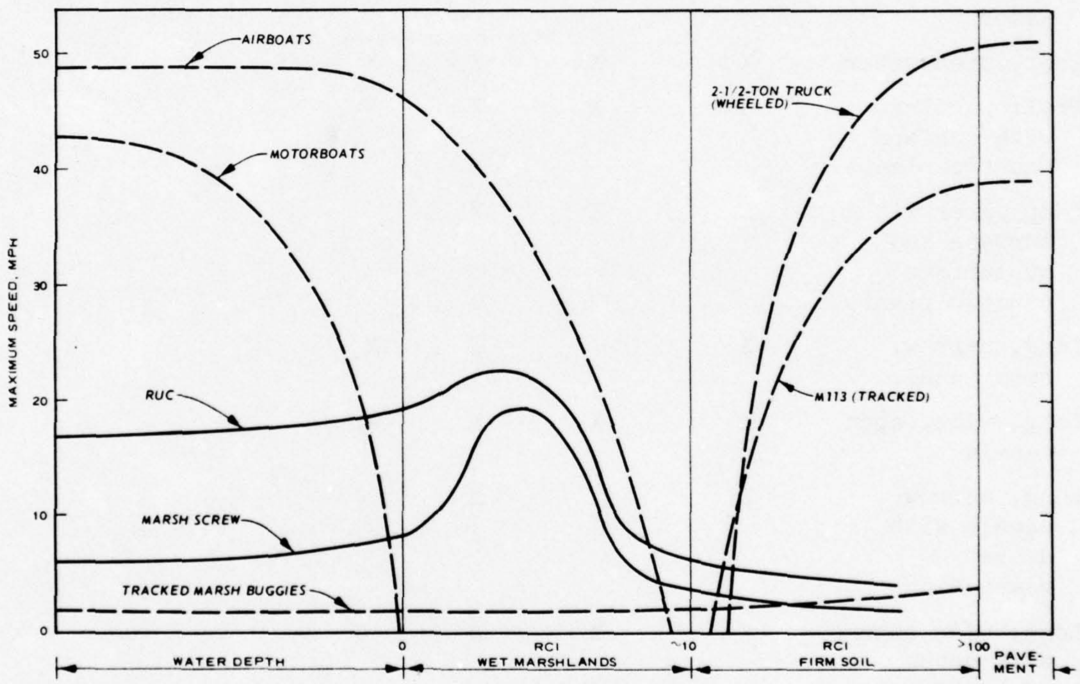

Figure 10. Comparison of relative performances of selected vehicles

the MSA with those of other types of land and water vehicles, throughout a range of conditions varying from open water to pavement.

32. The performance curves in Figure 10 represent data from several sources. Manufacturers' data were used to draw the curves representing airboat, motorboat, and tracked marsh buggy performance. The military vehicle performance curves were established from data collected

during the Mobility Exercise A field test program.[9] The performance curve for the RUC was plotted from data collected by the WES during tests conducted using the RUC in riverine environments.[10] The MSA performance curve resulted from trafficability tests conducted by the WES.[7] As shown in Figure 10, the screw machines (the MSA and the RUC) exhibit the best overall performances in wet marshlands. Airboats exhibit an acceptable performance range also; however, the speeds required to sustain forward motion over floating vegetation mats are too fast to allow application of liquid control agents. In addition, their maneuverability is more difficult in wooded marshlands where many aquatic plant problems exist.

Summary

33. The demonstration carried out in the three test areas was not intended to generate sufficient quantitative data to conclusively determine whether screw-propelled vehicles would be a low-cost adjunct to the New Orleans District's mix of machines used in its aquatic plant spray operation. Rather, it was directed toward giving the District personnel an opportunity to see how the MSA performed in typical operational environments and to determine if further studies of screw vehicles for use in aquatic plant control operations are warranted. The consensus of the observers of the demonstration was that there were five common areas or situation types in which they need to carry out control operations and in which they cannot maneuver adequately with their current assortment of boats. The areas or situation types referred to are: (a) canals with relatively deep water and with mats of large waterhyacinths completely choking the canals; (b) canals similar to (a) above but where petroleum company barges and large boats have packed the waterhyacinths very tightly in an effort to gain access to their wells or other exploration equipment; (c) flat areas of very shallow water and with thick mats of waterhyacinths; (d) flat areas with deep water choked with submerged aquatic vegetation; and (e) marsh areas in southern Louisiana where control operations are necessary but where great

distances must be travelled in a network of canals from one operation to another, rather than cross over short distances of marsh. Further, because these situations are so common in the New Orleans District, it was the consensus of the observers that further investigation of the use of screw-propelled vehicles in the New Orleans District is warranted. However, additional evaluation of the MSA in its present configuration is probably not warranted, even though the MSA appears to be the appropriate size and have the payload-carrying capacity to best serve as a transporter platform for herbicide application equipment in terrain areas of interest in aquatic plant control. The consensus of the observers was that the MSA in its present configuration has demonstrated the following deficiencies:

- a. Inadequate power to the rotors.
- b. Lack of sufficient space for payloads.
- c. Slow maximum water speeds.
- d. Buildup of debris beneath the vehicle, between the rotors.
- e. Poor steering on surfaces other than water and vegetation.
- f. A "nose-down" angle in the forward direction on vegetation densities.

34. The deficiencies above can probably be overcome by redesign as follows:

- a. Increase engine horsepower and power transmission capabilities.
- b. Extend a platform over the side of the existing machine as shown in Figure 11. This will allow an 8- by 6-ft platform with approximately 12.5 ft^3 of space available for storage beneath the platform for items such as water and herbicide.
- c. Redesign of rotor blade angles along the shape of those on the RUC, which had good water speed.
- d. Reverse rotor rotational direction for forward motion so that water and debris will move to the outside of the vehicle rather than to the hull section between the rotors.
- e. Shift center of gravity, when loaded, rearward.

35. Another design change that has potential is shown in Figure 12. This configuration is essentially two MSA's linked together.

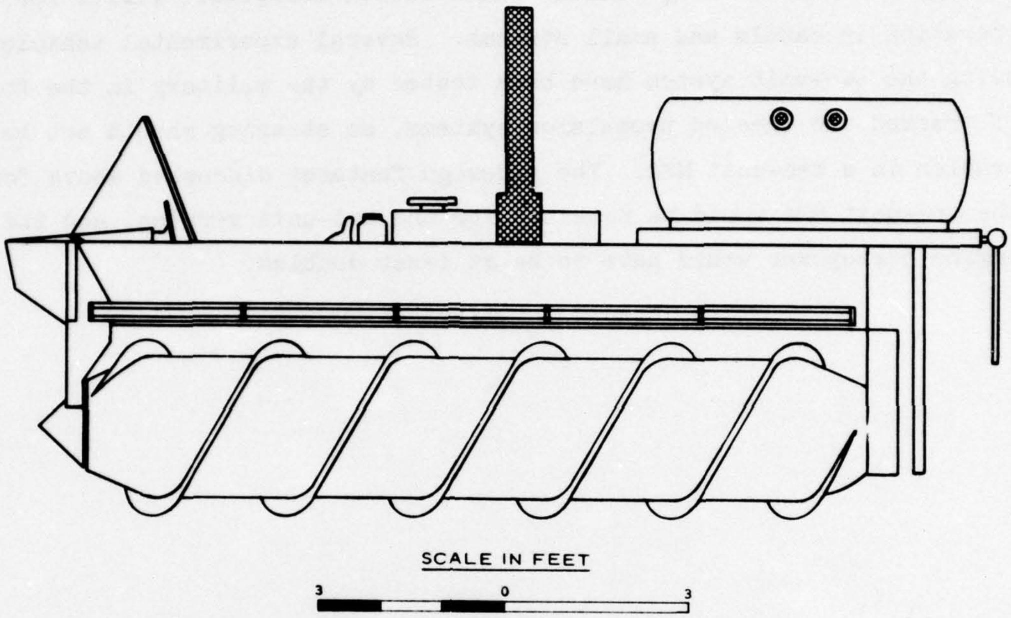

Figure 11. MSA with platform superimposed

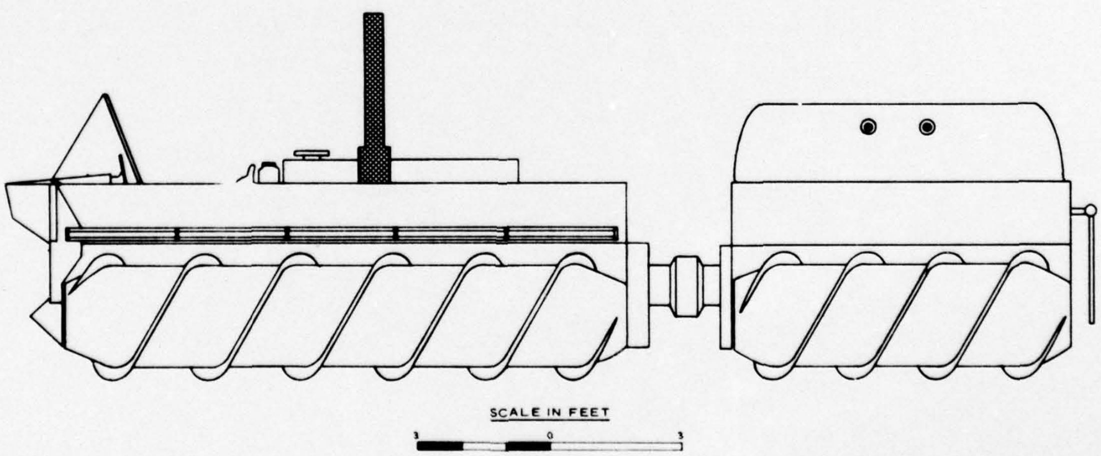

Figure 12. Proposed 2-unit articulated MSA

In this configuration, the entire rear unit would be available as a work platform, and the front unit would carry the engine and vehicle operator. Rotors on both units would be powered, and steering would be applied through connecting joints that are commercially available. This MSA configuration would keep vehicle width within acceptable limits for operation in canals and small streams. Several experimental vehicles using the two-unit system have been tested by the military in the form of tracked and wheeled propulsion systems, so steering should not be a problem in a two-unit MSA. The redesign features discussed above for the one-unit MSA would be retained for the two-unit version, and the engine horsepower would have to be at least doubled.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

36. As a result of testing the MSA in characteristic aquatic plant problem areas, the following conclusions were drawn:

a. The MSA demonstration clearly showed that screw-propelled vehicles have potential as application platforms for use in problem areas presently inaccessible to more conventional vehicles.

b. For an application platform using the screw propulsion system, the carrier should not be wider than the present MSA in order to travel in existing canals and woody vegetated swamplands.

c. Center of gravity should be toward the rear of the vehicle, so that it will have a "nose up" angle when operating in forward direction in dense floating vegetation.

d. In dense *floating vegetation*, the MSA occasionally experienced difficulty in the forward direction due to the rotor rotation propelling material to the inside of the rotors and beneath the hull.

Recommendations

37. Based on the conclusions above, it is recommended that:

a. The present MSA be modified to incorporate the following changes:

(1) Reverse rotational direction of rotors for forward propulsion.

(2) Shift center of gravity toward rear of vehicle.

(3) Increase horsepower.

b. The modified MSA be tested in aquatic plant problem areas.

c. Spray equipment be mounted on the MSA and operational problem areas be treated chemically as part of an operational problem.

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9. Schreiner, B. G., "Mobility Exercise A (MEXA) Field Test Program, Performance of MEXA and Three Military Vehicles in Soft Soil," Technical Report M-70-11, Report No. 2, Mar 1971, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

10. Schreiner, B. G., Smith, R. P., and Green, C. E., "Performance of Riverine Utility Craft (RUC) in Riverine Environments," Technical Report M-70-5, Apr 1970, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

11. Donahue Manufacturing, "Donahue Implement, Combine and Swather Carriers," Equipment Catalog, Durham, Kan.

Table 1

Data Collected During the MSA Demonstrations

Test Lane No.	Location	Lane Length m	Time to Complete Test sec	Average Speed km/hr	Vegetation Density (Weight per Unit Area) kg/m^2	Vegetation Height Above Water m	Mat Thickness (Below Waterline) m
1	New Orleans	30.0	68.2	1.6	5175.6	0.85	0.45
2	New Orleans	30.0	46.0	2.3	5175.6	0.85	0.45
3	Houma	150.0	64.8	8.3	1959.6	0.26	0.14
4	Houma	150.0	55.2	9.8	1959.6	0.26	0.14
5*	Houma canal crossing	21.5	12.5	6.2	No vegetation	--	--
6	Lake Boeuf open water	150.0	62.4	8.7	**	0.08	0.13†
7	Lake Boeuf open water	150.0	59.2	9.1	**	0.08	0.13†
8	Lake Boeuf Island	62.0	55.0	4.1	2456.5	0.73	0.70
9	Lake Boeuf Island	51.0	58.8	3.1	2456.5	0.73	0.70
10	Lake Boeuf Island	43.0	45.5	3.4	2456.5	0.73	0.70
11	Lake Boeuf Island	73.0	82.5	3.2	2456.5	0.73	0.70
12	Lake Boeuf Island	93.0	117.0	2.9	2456.5	0.73	0.70
13	Lake Boeuf canalled area	392.0	328.0	4.3	**	1.15	0.46†
14	Lake Boeuf canalled area	210.0	166.8	4.5	**	1.37	0.46†

* Test lane too short to determine maximum speed.
** Weights not obtained--vegetation types too scattered to obtain representative samples.
† Estimated--mat not uniform in thickness.

APPENDIX A: OTHER SCREW-PROPELLED MACHINES

Background

1. This appendix describes the RUC and AMFIROL screw-propelled vehicles and two conceptual machines, i.e. the Twilighter and the Amphibious Mud and Water Vehicle. Time did not permit a completely exhaustive search for all possibilities; however, those discussed herein are believed to cover the range in sizes and rotor configurations that have been seriously considered.

Riverine Utility Craft (RUC)

2. Screw-propelled devices for the propulsion of land and water vehicles have been experimented with for many years. Testing on only one other screw-propelled vehicle, besides the MSA, produced sufficient data to compare performances. This vehicle is the RUC, also manufactured by Chrysler Corporation for the Department of the Navy.[3*] Figure A1 shows a side view of the RUC; pertinent characteristics are tabulated on the following page.

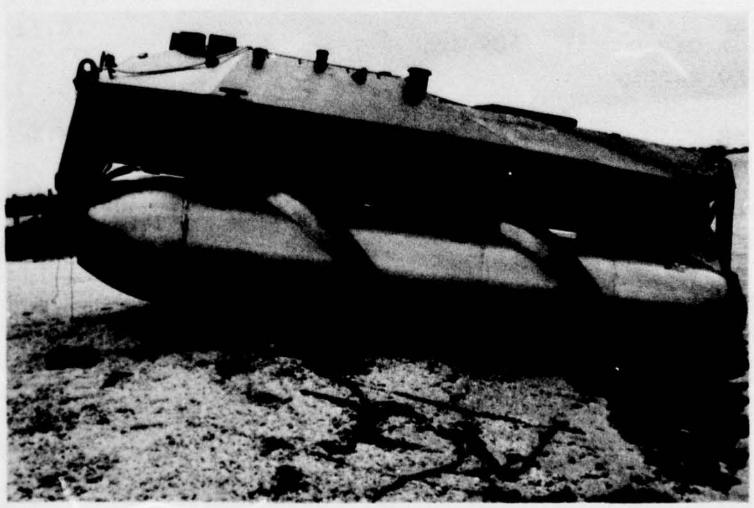

Figure A1. Side view of the RUC

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* Raised numbers refer to similarly numbered items in "References" at end of main text.

General	
Crew	2
Payload	5 passengers or 2000-lb cargo
Weight, gross:	
Cargo configuration	13,085 lb
Troop configuration	12,570 lb
Weight, net (less fuel, crew, cargo ammunition)	9,655 lb
Fuel tank capacity	340 gal

Dimensions	
Length, overall	242 in.
Beam, overall	168 in.
Height:	
From bottom of rotor w/canopy	137 in.
From bottom of rotor w/o canopy	104 in.
Rotor spacing (center to center)	110 in.
Rotor diameter (over drum)	39 in.
Rotor diameter (over helix)	58 in.
Ground clearance under hull	49 in.

Power Train	
Engine type	(2) Chrysler spark, ignition, water-cooled
Displacement	440 in.^{3}
Maximum speed	4500 rpm
Gross power	380 hp at 4500 rpm
Transmission type	(2) Chrysler torque-flite Model A727 2-speed automatic with torque convertor

Controls	
Steering type	Throttle steer
Smallest turning radius	Pivot
Shift position	Forward-neutral-reverse
Final drive:	
Upper	(2) Spiral bevel 4.11:1 ratio
Lower	(2) Spiral bevel 6.17:1 ratio
Overall ratio	5.3:1
Cooling system	(2) Radiator with engine-driven fan
Fuel	MIL-G-5572 grade 115-145 aviation fuel; MIL-G-3056 combat gasoline, for emergency use only

(Continued)

Performance

Maximum speed: (cargo configuration)		Fuel consumption (on water)	43 gal/hr
Water	27.7 km/hr	Obstacle climbing ability:	
Swamp and tidal flats	32.4 km/hr	Vertical rigid wall	20 in.
Snow	33.3 km/hr	Vertical earth wall	36 in.
Hard surface	5.5 km/hr (side mode)	Maximum trench crossing:	
Cruising range--8 hr @ 27.7 km/hr		Width	6 ft 8 in.

3. The RUC is a much larger vehicle than the MSA, and its improved mobility performance reflects knowledge gained from tests with the MSA and from extensive special studies on the design of buoyancy screw propulsion made by Chrysler. The rotor and helix blade angles were optimized for maximum speed in water, and the twin-engine power plant provides for adequate power in firm, dry soils and sticky clays. Both of these items were serious deficiencies in the MSA.

AMFIROL

4. This vehicle (Figure A2) is built by Machine Fabric of Holland, and is "... a special amphibious vessel or a work-floor, with which it is possible to enter grounds and areas, unapproachable with traditional

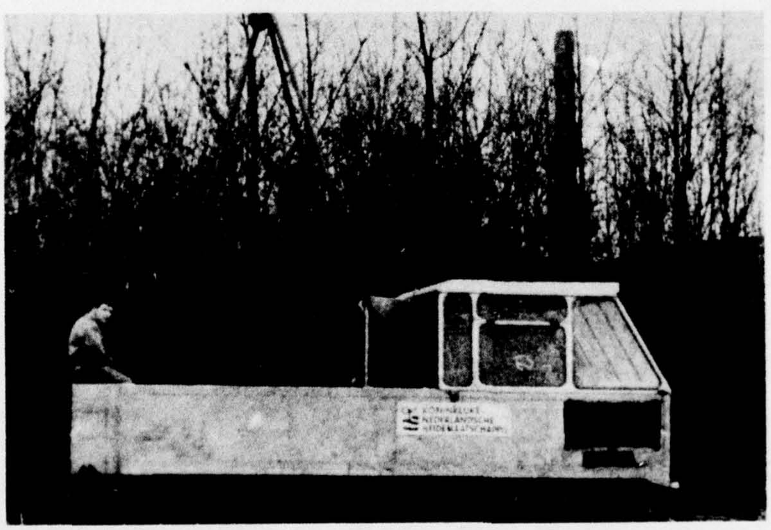


Figure A2. AMFIROL

means."[4] The rotors are more of the configuration of those of the MSA than those of the RUC. Some characteristics of the vehicle are:

<u>Size</u>	
Length, outside dimensions	5.6 m
Width, outside dimensions	3.0 m
Height, ground to top of work bed	2.0 m
<u>Speed</u>	
Open water	8-10 km/hr
Mud, snow, etc.	8-12 km/hr
Hard or dry ground	20-30 km/hr
Rugged ground	5-10 km/hr
<u>Weight</u>	
Empty	3500 kg
Loaded in water	6000 kg

Twilighter

5. The Twilighter[6] concept consists of a dual propulsion system as shown in Figure A3. Insofar as is known, this vehicle was never built

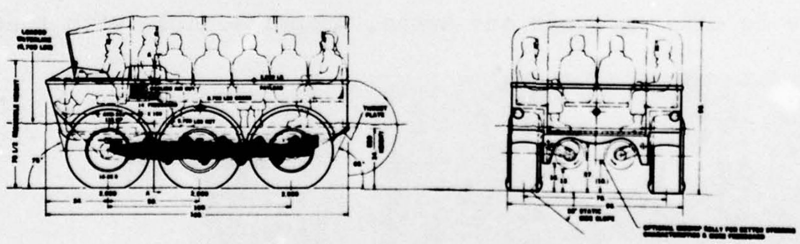


Figure A3. Twilighter

but does demonstrate that possible combinations of propulsion systems (incorporating the screw propulsion system) could eliminate, or at least relieve, the problems of screw movement on firm surfaces. The configuration as shown is primarily for wheeled locomotion with an emergency backup screw propulsion system if the vehicle becomes immobilized by sinking into soft soil. Conceivably, this combination could be adapted as an application platform if the screws were made larger and the wheels smaller. Such a combination of propulsion systems would eliminate the need for highway transporters, discussed in Appendix B.

Amphibious Mud and Water Vehicle

6. A patent was issued in January 1966 to Mr. Raymond G. Schrader for his invention of "... a multi-purpose vehicle which can be driven at relatively high speeds through mud and water, to facilitate its use in shallow water and in marshes and the like."[5] Figure A4 shows the drawing of this vehicle as it was submitted to the U. S. Patent Office. Contact was made with Mr. Schrader who indicated that he got the idea while in South America trying to navigate rivers "... choked up clean across with lily pads. Outboard (motor boats) could (not) go through it, for it would break the propeller blades." Specific size and weight are not mentioned, but the patent description indicates it will carry four people (payload of about 800 lb), and the overall width is about 3-1/2 ft and length is about 12 ft. Power should be supplied by a 200- to 500-hp engine. The rotors should be about 1 ft in diameter and about 6 ft long. No vehicles have been built according to this design.

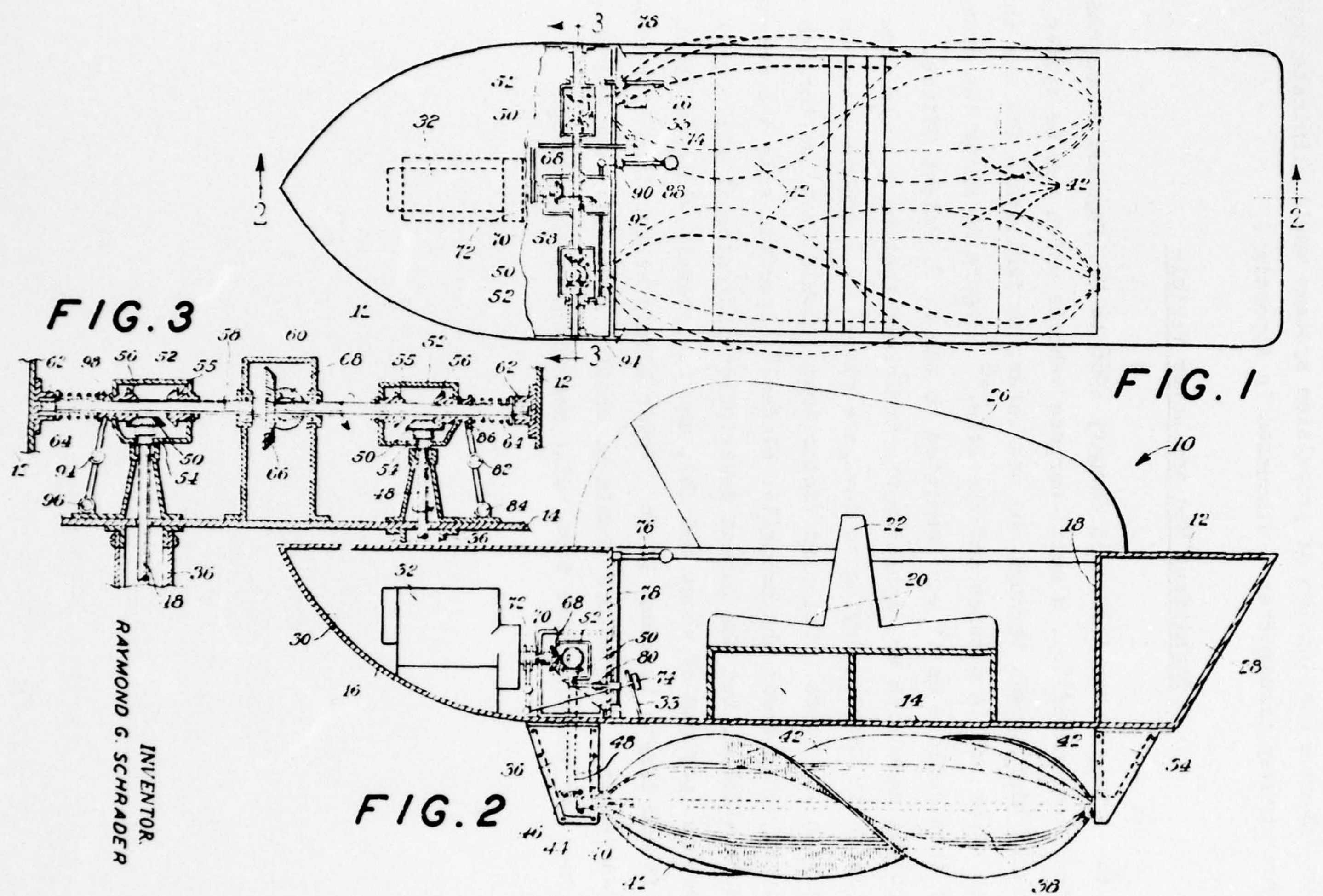


Figure A4. R. G. Schrader's Amphibious Mud and Water Vehicle

APPENDIX B: HIGHWAY TRANSPORTERS FOR SCREW-PROPELLED VEHICLES

1. It is obvious that movement of screw-propelled vehicles on hard surfaces for any distances will have to be by means other than their propulsion systems. The best transport system thus far developed seems to be the modified boat trailer shown in Figure B1 for the MSA, which

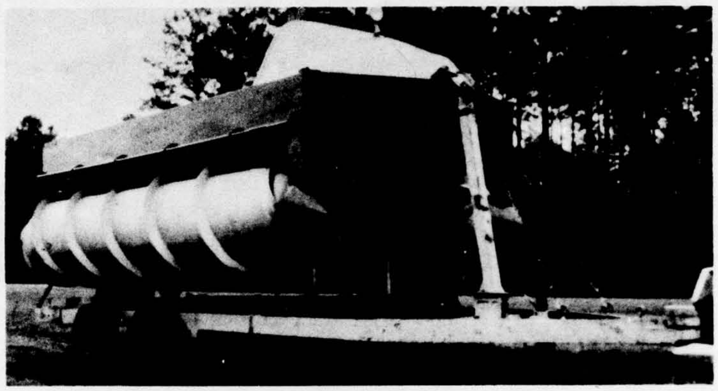


Figure B1. Modified boat trailer for transporting the MSA

can be backed down a ramp into a water body and the MSA launched as a boat. This particular trailer has the capability of loading and unloading the MSA on firm ground, but with some difficulty, by use of a center platform made of a series of rollers and a hand winch. The trailer and MSA can be towed by a pickup truck or a medium-sized station wagon.

2. The AMFIROL uses a low-bed trailer and plank ramp, as shown in Figure B2. It is not known if this is a specially built trailer or a standard utility equipment trailer. Apparently, the vehicle is loaded sideways by rolling it up the ramp while the trailer is standing on a firm surface; the trailer is not used for launching the vehicle in water.

3. Another trailer system (Figure B3) that appears to be applicable for screw-propelled vehicles is made in various sizes and patented by the Donahue Company.[11] It is unique in its ability to slide the platform forward off of the axle assembly; after a load is rolled onto

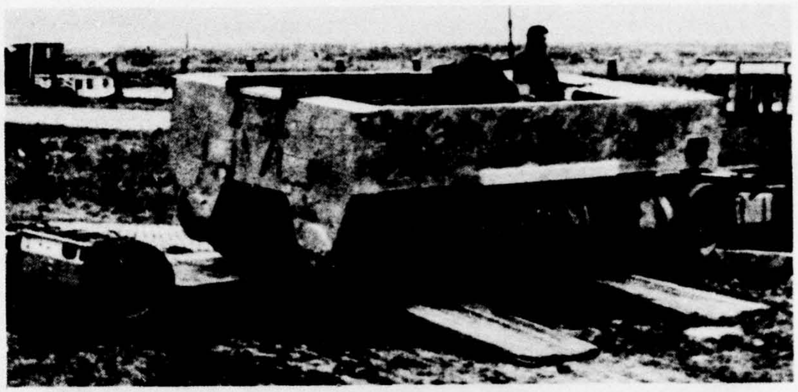
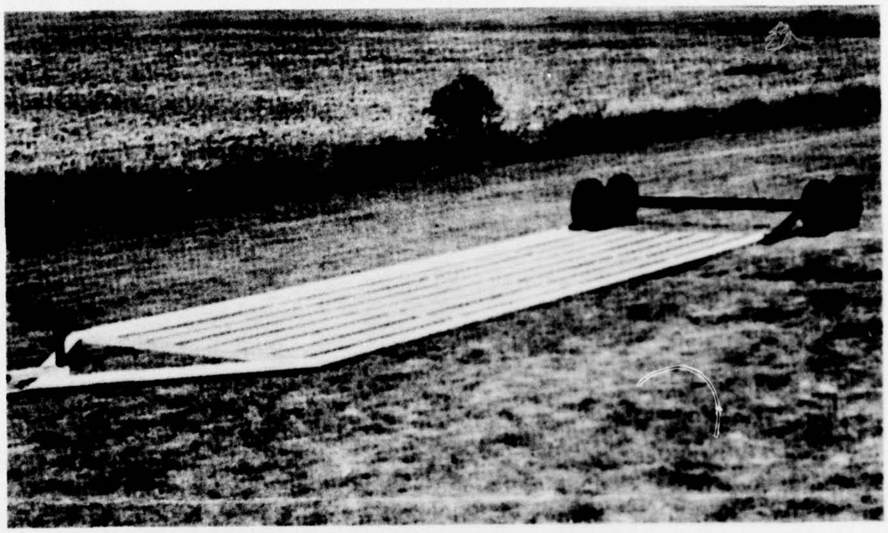
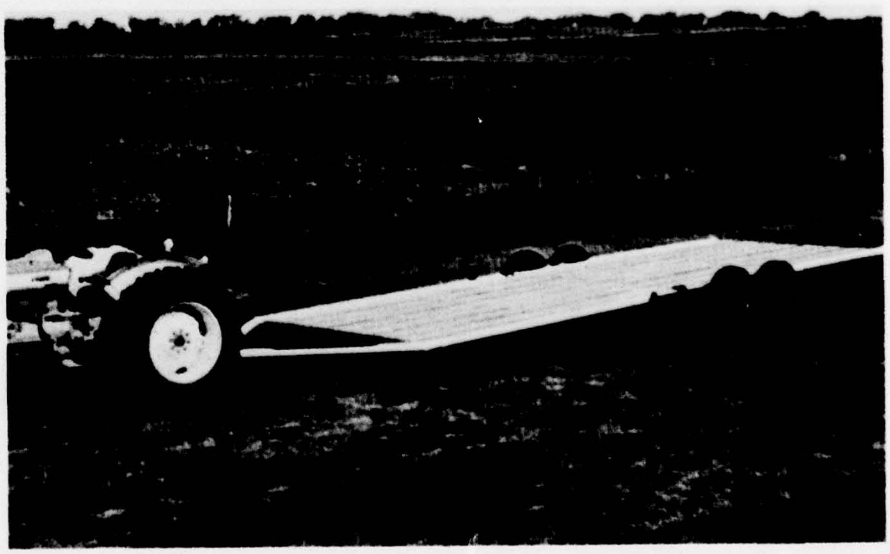


Figure B2. Low-bed trailer for transporting the AMFIROL

the platform, the platform is then placed on the axle assembly for highway transportation. All movement is accomplished by locking the wheels of the trailer and pulling or pushing the platform with the prime mover. This trailer is being used successfully by plantation owners for hauling large pieces of farm equipment. Loading of a screw-propelled vehicle would be accomplished by rolling it on and off the trailer sideways.



a. Loading position



b. Transporting position

Figure B3. Donahue trailer

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Rush, Edgar S
Evaluation of herbicide application platforms for use in aquatic plant control; Report 1: Evaluation of the Marsh Screw Amphibian (MSA), by Edgar S. Rush [and] William E. Willoughby. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report A-77-1, Report 1)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.
Includes bibliography.

1. Aquatic plant control. 2. Herbicides. 3. Marsh Screw Amphibian. 4. Screw propelled vehicles. I. Willoughby, William E., joint author. II. U. S. Army. Corps of Engineers. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report A-77-1, Report 1)
TA7.W34 no.A-77-1 Report 1